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Nutritional studies on crab meat

Vernon Kenneth Watson
University of Massachusetts Amherst

NUTRITIONAL STUDIES ON CRAB MEAT

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TABLE OF CONTENTS

I. INTRODUCTION

This study is concerned with two species of crabs of importance on the Atlantic Coast. They are Callinectes sapidus, known as the blue crab and Platyonichus ocellatus, Latreille, known as the sand crab.

The blue crab is the most abundant and, next to the lobster, the most important crustacean of our waters. Its range is from Massachusetts Bay to South America. It is common from Cape Cod to Texas. Deleware Bay, Chesapeake Bay and the protected channels along the south Atlantic and Gulf Coasts swarm with blue crabs. Chesapeake Bay is especially favorable and has long been famous not only for the great number, but also for the size of the crabs which it produces. The blue crab is caught and marketed in both soft-shell and hard-shell conditions. For the most part they are eaten fresh. A small but increasing number are canned.

The sand crab, also known as the lady crab, is abundant on nearly all our sandy shores from Cape Cod to Florida, and in the Gulf of Mexico. This species is used as bait on many parts of the coast. It is also an important article of food.

When one considers that in a year, using 1932 as an example, that the total catch of crabs for the United States and Alaska amounted to 81,453,000 pounds worth 1,501,000 dollars, it is evident that a large amount of crab meat is consumed and that information concerning its nutritive value would be of interest. The object of this study is to determine the biological value of the protein of the blue and sand crabs and to obtain information regarding ~~some of~~ the chemical

composition of the edible portion of these two crabs.

A search of the literature revealed no determinations of the biological value of the protein of either the blue or sand crabs and no analyses for any of the inorganic constituents of the sand crab meat.

II. REVIEW OF LITERATURE

1. Proximate Analysis

A number of proximate analyses of several species of crabs, including the blue crab, were found. Table 1 shows the proximate analyses of Chionectes phalangium Fabr., Paralithodes camtchatica Tilesius, Grapsus nankin, Cancer magister, and Callinectes sapidus.

These scanty data show meat, from the several species which have been examined, to be realtively constant in composition. The protein and ash are high and the fat content relatively low, though the amount of the latter varies with the season as shown by Parks and Fellers (14).

2. Protein

Osborne and Mendel have done much to establish the conception that the nutritive value of proteins is largely determined by the amounts of each of the amino acids which they yield. Several investigators (20) (21) (25) have determined the cleavage products resulting from the hydrolysis of the crab meat protein. All of the essential amino acids are present. Table 2 shows the percent of the essential amino acids in the protein of two species as compared with that of beef protein.

Suzuki, Matsuyama and Hashimoto (30) studied the relative values of various proteins contained in Japanese food articles including the "talapa" crab. Normal growth resulted when rats were fed this at a

ten percent level. When the protein was fed at a seven percent level, crab gave nearly the same results as beef.

3. Vitamins

A search of the literature as covered by Chemical Abstracts revealed only one study of the vitamins in crab meat. Shimoda (29) fed ether extracts of the meat of several species of crabs, in different amounts to albino rats. The rats grew when a 5 - 10 mg. dose was fed, while rats not receiving any of the extract failed to grow. This may be interpreted to mean that vitamin A is present.

4. Mineral Content

Newell and McCollum (24) conducted spectroscopic analyses of a number of marine products including crabs. In all of the products examined calcium, iron, magnesium, phosphorus, potassium and sodium were detected spectroscopically in considerable amounts. Traces of aluminum, chromium, copper, lead, lithium, manganese and strontium were detected in all products. Other rarer elements were found in some of the products.

There is a lack of analytical data concerning the mineral constituents of crab meat. A survey of the literature showed that in addition to the proximate analysis of crab meat only the elements, arsenic, copper, iodine, lead, phosphorus, and zinc, have been determined quantitatively in crab meat. Table 3 gives the mineral analyses of crab meat reported in the literature.

These scanty data show a high iodine content. Single analyses indicate high arsenic and copper in some species. On the whole too few determinations are available on which to base a valid statement concerning the mineral constituents of crab meat.

III. EXPERIMENTAL PART

1. Analytical Methods

a. Sampling

The objective in sampling was to obtain a representative sample. The crab meat was removed from its containers and spread in a thin layer over the surfaces of a number of large shallow glass dishes. In this condition the crab meat was placed in an oven and dried in a current of air at 35 to 40 degrees Centigrade. Eighteen hours was sufficient to insure drying. Eight or nine pounds of each of the crab meats were dried in this manner and ground to a fine powder in a mill. The dried crab meat was passed through the mill two times. The crab meat in this condition was suitable not only for the analyses but it was in a condition to be incorporated in the rations for the feeding experiments.

b. Determination of Moisture

Approximately 10 grams of the crab meat was placed in a large weighing bottle and accurately weighed. The crab meat was dried to constant weight in a hot air oven at 70 to 75 degrees Centigrade.

c. Determination of Total Ash

The determination of the percentage of total ash was made according to the official methods of the A.O.A.C. (1). The alkalinity of the ash was likewise determined in accordance with these methods. (6).

d. Determination of Nitrogen

The Kjeldahl-Gunning method, as outlined in the methods of the A.O.A.C. (2), was followed in the determination of nitrogen. The percent of protein was obtained by multiplying the percent of nitrogen by 6.25.

e. Determination of Ether Extract (fat)

The determination of the ether extract was made according to the official methods of the A.O.A.C. (3).

f. Preparation of Ash Solutions

The analyses for the various inorganic constituents in the crab meat were determined on aliquots of an ash solution. Ten grams of finely ground air dried crab meat were transferred to a 250 cc. porcelain dish. To this was added 25 cc. of distilled water redistilled from glass and 10 cc. of sulphuric acid (1 to 1). This was evaporated to dryness on a water bath and then heated carefully on an asbestos board over an electric heater followed by an electric muffle at low heat until the carbon was substantially

destroyed. After it had cooled, 25 cc. of water and 5 cc. of sulphuric acid (1 to 1) were added, and the material treated as previously described, repeating the process until a white ash was obtained.

Twenty-five cc. of water, 10 cc. of concentrated hydrochloric acid and 5 cc. of concentrated nitric acid were added and the solution evaporated to dryness on a water bath. It was then taken up with 25 cc. of water and 10 cc. of concentrated hydrochloric acid and evaporated to dryness. After this it was taken up with water and 15 cc. of concentrated hydrochloric acid, heated, transferred to a 500 cc. volumetric flask, boiled 5 minutes, cooled, made up to volume at 25 degrees Centigrade, filtered and the ash constituent determined in aliquots of the solution.

g. Determination of Calcium and Magnesium

The procedures followed for the determination of calcium and magnesium were the official methods of the A.O.A.C. (4). The determinations were made on aliquots of the ash solutions prepared as described above.

h. Determination of Phosphorus

Phosphorus was determined colorimetrically by the method of Fiske and Subbarow (15). An aliquot of the ash solution was evaporated to dryness with sulphuric acid, and then taken up again with sulphuric acid. Ammonium molybdate was added to the solution and the ammonium phosphomolybdate formed was reduced to molybdenum blue by the addition of alpha-aminonaphtholsulphonic acid. The color

produced was compared with an aliquot of a standard phosphorus solution which had been similarly treated.

i. Determination of Iron

The procedure followed for the estimation of iron was essentially that of McFarlane (23). An aliquot of the ash solution was evaporated to dryness with a few drops of perchloric acid. The residue was taken up with nitric and hydrochloric acids and a colored iron salt produced with potassium thiocyanate. The color thus produced was compared with that produced in a similarly treated standard iron solution.

j. Determination of Copper

Copper was determined by a modification of the carbamate method (9) (22). The procedure, as modified, is that used by the Experiment Station at the Massachusetts State College. A 100 cc. aliquot of the original ash solution was evaporated to dryness with three drops of perchloric acid in a 150 cc. Griffin beaker on a steam bath. The residue was taken up with three cc. of hydrochloric acid (1 to 1) and 10 cc. of water and warmed on a steam bath. Three cubic centimeters of sodium pyrophosphate were added and concentrated ammonium hydroxide added, drop by drop, until the solution was alkaline to litmus. The solution was transferred to centrifuge tubes and washed five times with five cc. of water. It was then centrifuged at 1600 r.p.m. for five minutes. The solution was then transferred to a 100 cc. stoppered graduate. Ten cubic centimeters of water were added to the centrifuge tube, the curd broken up and washed with 10 cc. of water. The contents

of the centrifuge tube were centrifuged again for five minutes and transferred to the same graduated cylinder. The residue was washed and centrifuged again, and the solution poured into the cylinder. The cylinder was stoppered and heated in a steam bath at 80 degrees Centigrade for 15 minutes. The solution was cooled and made up to 89 cc. with copper-free water. One cubic centimeter of sodium diethyldithiocarbamate solution and 10 cc. of isoamyl alcohol were added. The cylinder was stoppered and shaken for about two minutes. The layer of isoamyl alcohol containing the colored copper salt was removed by means of a separatory funnel and filtered through filter paper to remove traces of moisture. The color was compared in a Duboscq colorimeter, using micro-cups, against five cc. of a standard copper solution (1 cc. contained 0.00001 gram of copper) treated in exactly the same manner.

k. Determination of Manganese

Manganese was determined according to the method of Willard and Greathouse (35). The method is based on the oxidation, by potassium periodate, of manganese from the bivalent to the heptavalent condition in an acid solution. An aliquot of the ash solution was evaporated with nitric and sulphuric acids to fumes of the latter to remove chlorides. Concentrated phosphoric acid was added (2 cc. of concentrated phosphoric acid to every 10 cc. of solution being treated) and 0.2 gram of potassium periodate. The periodate must be added after the acid has been added, otherwise intermediate products of manganese are likely to form. The mixture was boiled for about one minute, after which it

was allowed to stand on a hot sand bath for five minutes. Following this it was put in a Nessler tube, diluted to 50 cc. and compared with standards prepared in the same manner. Due to presence of periodate in excess the standards may be kept for three months before it is necessary to make a new set.

1. Proximate Analysis

Table 4 shows the results of the proximate analyses of the edible portions of the two species of crab. Each va lue given is the result of four determinations.

The colorific value of the crab meat was calculated using Sherman's factors of 9 for fat and 4 for each protein and carbolydrate. The calorific value of the meat is only moderate.

2. Partial Composition of the Ash

The results of the partial analysis of the ash are expressed in percent of the dry material in Table 5. The values in each case are the result of duplicate determinations. The values for the various constituents in the moist edible portions would be approximately one-fifth the values given.

The alkalinity of the ash is also included in Table 5. It is expressed in cubic centimeters of normal acid required to neutralize the ash from 100 grams of the edible material and is calculated to both the wet and dry bases.

The meats of both the sand crab and the blue crab contain a high percentage of ash. A characteristic of the crab meat ash is its high

alkalinity. The ash from 100 grams of the edible material is equivalent to 11 to 12 cubic centimeters of normal alkali. A survey of the data from Sherman (28) as shown in Table 6 reveals that crab meat, as determined in the present study, is one of the better sources of "potential alkalinity."

3. Biological Value of the Crab Meat Protein

The biological value of the crab meat protein was determined by two feeding experiments with albino rats. Diets were used which supplied everything necessary for growth and which were alike except in the source of protein. Table 6 shows the general composition of the diets. The composition of the salt mixture used is shown also in Table 6. The diets were made to balance calorifically by adjusting the amounts of untreated starch and butter oil. All of the ingredients except the butter oil and the cod liver oil were mixed. The butter oil and the cod liver were placed in the bottom of a steam jacketed kettle until the butter had melted. Then the other ingredients which had been thoroughly mixed were added and mixed with the oils. The material was passed through a sieve several times to be sure that no lumps were present and to insure a uniform composition.

The butter oil used in the diets was treated to remove all of the salt and protein of the butter. The butter was placed in a large glass jar of the clamp top type. The jar was filled with warm water, sealed, and inverted in a water bath automatically held at a temperature of 75 degrees Centigrade. After the butter had melted, the jar was thoroughly shaken, replaced in the water bath in an inverted position,

and allowed to remain several hours. The emulsion gradually separated until the fat rose to the bottom of the inverted jar, while the water remained below. When a good separation had occurred, the jar was carefully removed from the water bath and placed, still inverted, in a cold room at about 2 degrees Centigrade until the fat had solidified. The inverted jar was then opened over a sink so that the water, carrying practically all of the salt and protein of the butter, could run off. The surface of the solidified fat was scraped with a spatula to remove the adhering protein. The fat was then remelted and the clear golden liquid decanted, leaving the last traces of the protein and water behind. Because the crab meat itself contained some fat, an equivalent amount was deducted from the amount of butter oil to be added to the diet.

The treated starch used in the diet was that on which the wheat germ extract was dried. This supplied vitamins B and G. The extract was prepared by extracting the wheat germ with 70 percent alcohol. In the first extraction allowance was made for an estimated 10 percent of water in the wheat germ. The alcohol was heated in a tightly covered pressure cooker in a water bath automatically held at 65 degrees Centigrade. When this temperature was reached, the wheat germ was added to the hot solution. Enough pre-heated 70 percent alcohol was added to cover the wheat germ. The pressure cooker was sealed and immersed in the 65 degree water bath for an hour. It was then removed and opened, and the wheat germ was placed in a small press. The alcoholic solution was pressed out. Two more extractions were made in this way.

The combined extractions were allowed to stand over night, then were filtered free of suspended protein, and finally concentrated in a vacuum pan at approximately 20 inches of vacuum. The extract was then dried down on an amount of starch equivalent to two percent more than the weight of the original wheat germ. The treated starch was ground to a powder and incorporated in each ration at a 12 percent level.

The crab meat was dried in a current of air at a temperature between 35 and 40 degrees Centigrade, and pulverized. Two diets were prepared from frozen sand crab, one from frozen blue crab, and one from canned blue crab. Each ration was made up to contain nine percent protein (N x 6.25). The growth of rats on the diets containing crab meat was compared with the growth of those on a diet containing casein as the sole source of protein. In one test the casein control contained vitamin-free casein and in the other test technical casein was used.

Each ration was fed to eight albino rats for a period of 35 days. The rats were housed in individual cages as shown in Fig. I., and a n accurate record was kept of the food consumed. The rats were weighed every five days during the tests. Figure II. shows the average change in weight for the rats on each diet.

RESULTS OF FEEDING TRIALS

The gain in weight per gram of protein consumed was 2.3 grams for the rats fed the diet containing the meat of the frozen sand crab. The rats on this diet made an average gain of 60.8 grams during the 35 days of the test. For the rats on the diet containing

the frozen blue crab meat, the gain in weight per gram of protein consumed was also 2.3 grams. The rats on the latter diet made an average gain of 65.7 grams during the same period. The rats on the canned blue crab diet made an average gain of 25.2 grams during the 35 days test period. The rats on the control diet containing the technical casein made no appreciable gains in weight. The rats receiving the highly purified casein as a sole source of protein lost weight and died. By the thirty-fifth day of the test the rats on the purified casein had lost on the average of 7.5 grams. At this point they were switched to the sand crab diet and in 10 days the average gain per rat was 16 grams.

Figures III, IV, and V, show photographs of representative rats on each of the diets at the conclusion of the experiment. At the end of the experiment the weights of the rats in each group were averaged and the rat in each group whose weight was nearest to the average for the group was selected for photographing. Figure III shows a rat representative of the rats on the sand crab diet corresponding to growth curve No. 2 on the graph. Figure IV shows a rat representative of those that were fed the frozen blue crab diet. Figure V shows the representative rat of the group that was fed the technical casein. No photographs were made of the rats in the first experiment which included feeding tests with canned blue crab, frozen sand crab and vitamin-free casein.

The results of the feeding experiments indicate that the two frozen crab meats have about the same nutritive value. The experiments also indicate that the canned blue crab is not as satisfactory

as the frozen blue crab meat for rats as a sole source of protein. Apparently the crab meat lost considerable of its growth promoting value for rats by the treatment to which it was subjected in the process of canning. The crab meat protein sustains growth in rats far better than ordinary or highly purified casein. The manner in which the control rats gained in weight when changed to the sand crab diet is indicative of the superiority of the crab meat protein over that of casein for rat growth. The value of the frozen crab meat protein was almost equal to that of beef protein as determined by Hoagland and Snider (17) in a similarly conducted experiment. They found that rats fed beef protein at a 10 percent level gained, on an average, 2.5 grams in weight for each gram of protein consumed. As mentioned above, the value found for both of the frozen crab meat proteins was 2.3 grams. Suzuki, Matsuyama and Hashimoto (30), as mentioned in the review of the literature, found the protein of the "talapa" crab to have nearly the same value as beef.

SUMMARY

1. The literature on the composition of the flesh of crabs and its nutritive value is reviewed.

2. The sand crab, Platyonichus ocellatus, and the blue crab. Callinectes sapidus are very similar in composition and food value.

3. The data obtained in the present study are believed to be the only ones available on the sand crab. Many of the data on the blue crab are also new.

4. Crab meat may be described as a high protein and high mineral food of medium calorific value.

5. The ash alkalinity is realtively high as is also the calcium, phosphorus, iron and copper content.

6. Rat growth tests of the biological value of the proteins of crab flesh show that crab protein is definitely superior to casein as a sole source of protein for rats. There was little difference in this respect between the sand and blue crabs.

7. One sample of canned blue crab was somewhat inferior in protein quality to the frozen blue crab.

8. Technical grade casein and "vitamin-free" casein when compared as sources of protein for rats gave very similar growth curves.

9. A comparison of these data with reported results on meats, indicate that crab meat protein has approximately the same biological value as beef.

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Table 1. Proximate Composition of Various Species of Crabs (moist basis)

	Moisture	Protein	Fat	Ash	Carbohydrates
Chionectes phalangium Fabr.	Percent 77.65	Percent 19.35	Percent 0.85	Percent 1.95	Percent 0.23
Hatakoshi (16)					
Paralithodes camtchatica Tilesius	77.69	19.48	0.29	1.77	0.74
Kondo and Iwamae (20)					
Paralithodes camtchatica	77.65	17.54	2.58	1.53	____
Fellers and Parks (14)					
Grapsus nankin	____	____	0.21	4.88	____
Lin (21)					
Cancer Magister	80.98	15.52	1.82		0.2 - 0.5
Fellers and Parks (14)					
Callinectes sapidus					
Fresh	77.07	16.64	1.96		3.30
Canned	79.97	15.80	1.54	1.94	____
Tressler (31)					

Table 2. Cleavage Products in Percentage of Ash - and Moisture-free Substance

	Beef*	Paralithodes camtchatica (25)	Grapsus nankin (20)
Tyrosine	2.20	1.87	5.62
Tryptophane	present	present	1.48
Lysine	7.59	5.88	9.74
Cystine	#	#	1.74
Histidine	1.76	2.21	2.12
Arginine	7.47	8.75	7.54

* Osborne and Jones, Amer. Journ. Physiol., 24, 437, 1909
# Not determined

Table 3. Amounts of Various Elements Reported in the Meat of Several Species of Crabs (Moist Basis)

Species	P	Cu	Zn	I	Pb	As
	percent	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
Crapsus nankin Lin (21)	0.58					
Eastern Crab Rose and Bodansky (26)		5	0.021			
Blue Crab (Callinectes sapidus) Tressler and Wells (32)				0.180		
Cancer magister Fellers and Parks (14)				0.102		
Paralithodes camtchatica (14)				0.362		
Soft Crab (probably Callenectes sapidus) Wells (34)				0.490*		
Japanese crab (canned) Wells (34)				0.740		
Callinectes hastatus Severy (27)		2.50	30.97			
Crab (species not given) Chapman (10) Chapman and Linden (11)		130			17	45.6

* dry basis

Table 4. Proximate Composition of the Edible Meat of the Blue Crab and Sand Crab

Determination	Blue Crab		Sand Crab	
	Moist Basis	Dry Basis	Moist Basis	Dry Basis
	Percent		Percent	
Moisture	79.04		76.28	
Dry Matter	20.96		23.72	
Ash	2.15	10.28	1.77	7.45
Crude Protein (N x 6.25)	17.95	85.62	20.28	85.49
Ether Extract (fat)	0.39	1.86	0.24	1.03
Carbohydrates (by diff.)	0.47	2.24	1.43	6.03
Calories per 100 grams (Sherman)	77.2		89.8	
Alkalinity of Ash*	11.65	55.60	12.87	54.30

* Cubic centimeters of normal acid required to neutralize the ash from 100 grams of crab meat.

Table 5. Partial Composition of Ash (Dry Basis)

	Blue Crab percent			Sand Crab percent		
	I	II	Average	I	II	Average
CaO	0.886	0.892	0.889	0.891	0.897	0.894
MgO	0.090	0.098	0.094	0.068	0.062	0.065
P_2O_5	0.437	0.395	0.416	0.434	0.478	0.456
Fe	0.0094	0.0094	0.0094	0.0072	0.0069	0.0071
Cu	0.0060	0.0061	0.0061	0.0054	0.0056	0.0055
Mn	trace	trace	trace	trace	trace	trace
I (parts per billion)	1,270	1,900	1,585	2,110	2,320	2,215
K_2O	9.86	11.76	10.81	8.98	8.69	8.84

Table 6. Potential Alkalinity of Foods

Food	Alkalinity of ash in terms of cc. of normal alkali per 100 g. of edible portion
Spinach	27.0
Raisins	23.7
Dried Beans	18.0
Dates	13.9
CRAB MEAT	12.3
Carrots	10.8
Lettuce	7.4
Potatoes	7.0
Tomatoes	5.6
Oranges	5.6
Lemons	5.5
Grape Juice	3.9
Apples	3.7
White Bread	acid
Meat	acid

Data except crab meat and dates taken from Sherman (28). The datum on dates is taken from Cleveland (12).

Table 7

Composition of Diet for Feeding Experiment

	Percent
Protein	9.0
Butter Oil	3.0
Cod Liver Oil	2.0
Agar	2.0
Salt Mixture*	2.9
Treated Starch	12.0
Untreated Starch	65.9
$CaCO_3$	1.5
KH_2PO_4	1.7

Salt Mixture *

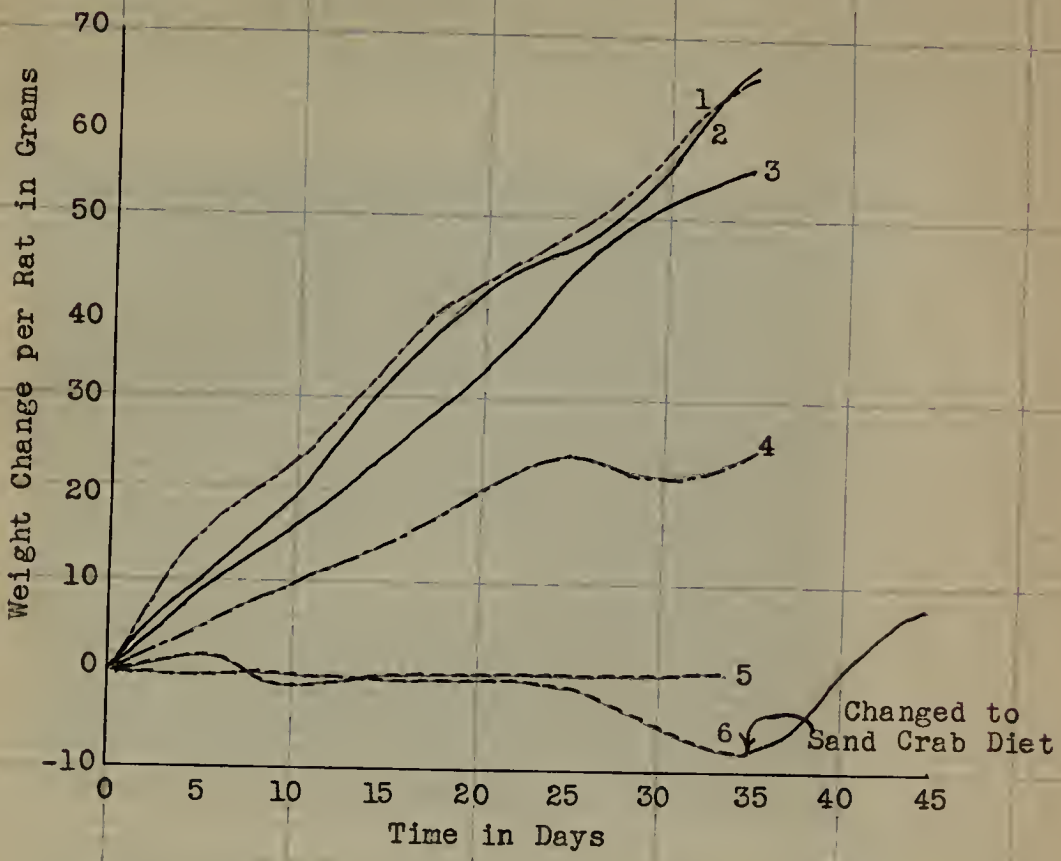
KCl	300.00 grams
NaCl	150.00 "
$NaHCO_3$	210.00 "
Fe citrate	150.00 "
MgO	60.00 "
$K_2SO_4Al_2(SO_4)_3 \cdot 24 H_2O$	36.67 "
NaF	4 . 57 "
$MnSO_4 \cdot 4 H_2O$	8.62 "
KI	2.74 "

* Combination of McCollum's Salt Mixture No. 1 (13) with a supplementary mixture used by Bing and coworkers (7).

Fig. I

Rack with individual cages for feeding experiment.

Figure II. Comparison of the Biological Value of the Protein of the Blue and Sand Crabs with that of Casein at a 9 Percent Level



-.-.-. Blue Crab Diets (1) Frozen (4) Canned

(2) (3) Frozen Sand Crab Diets

------- Casein Diets
(5) Technical Casein
(6) Vitamin-Free Casein

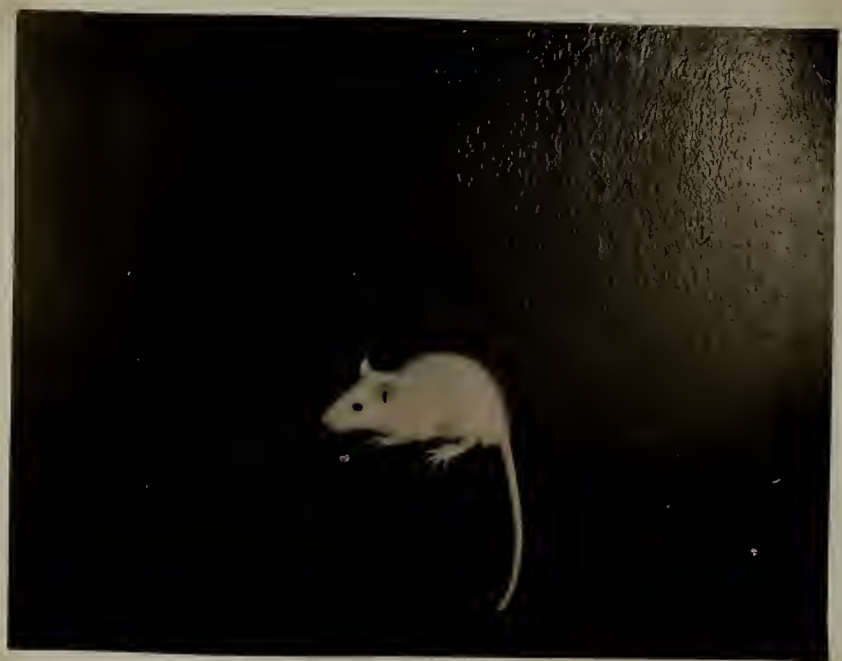
Fig. III

A representative rat from the group on the sand crab diet.

Fig. IV

A representative rat from the group on the frozen blue crab diet.

Fig. V



A representative from the group on the diet containing the technical casein.

Approved by

C. R. Fellers

James E. Fuller

C. A. Peters

Graduate Committee

Date May 18, 1935